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The cyclical dynamics of illiquid housing, debt, and foreclosures

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This paper quantitatively accounts for the cyclical dynamics of key macroeconomic housing and mortgage market variables using a tractable, search-theoretic model of housing with equilibrium mortgage default. To explain these dynamics, the model highlights the importance of liquidity spirals that arise from the interaction of search frictions and endogenous credit constraints. During housing busts, longer selling times spill over into higher foreclosure risk, thereby magnifying the response of credit constraints to the depressed housing market. This contraction in credit then deepens the downturn. During booms, the reverse occurs. Based on these insights, I consider a foreclosure reform that makes all mortgages full recourse, and I show that implementing such a reform would reduce foreclosures and dampen housing dynamics.

Keywords. Housing, liquidity, search theory, credit constraints, household debt, foreclosure.

JEL classification. D31, D83, E21, E22, G11, G12, G21, R21, R31.

1. Introduction

Much has been written about the recent unprecedented boom and bust in the U.S. housing market, which saw real house prices climb by 60% between 1998 and 2005 before subsequently falling by 30% from 2006 to 2010. House sales followed a similar run up and collapse, and many people have argued that the surge in foreclosure activity helped precipitate the Great Recession. Although frequently overlooked, months supply[1]—a measure that reflects average time on the market—exhibited equally dramatic behavior, jumping from 4 months to over 11 months at the trough of the bust. This paper draws motivation from the experience of the past decade but takes a step back to look at the behavior of housing market dynamics over the period 1975–2010.

Despite the fact that the housing and mortgage markets have undergone significant changes in the past two decades, some striking patterns emerge that link previous

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[1] Months supply equals the ratio of unsold inventories to the sales rate.

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housing cycles to the one the United States just went through. First, *real* house prices, sales, and residential investment are procyclical and substantially more volatile than output. In fact, the high volatility of house prices remains a particularly difficult fact for the housing literature to explain. Months supply and foreclosures also demonstrate high volatility compared to output, but they move in a countercyclical manner. Prior to the Great Recession, months supply skyrocketed into the double digits during the early 1980s housing bust and nearly reached that level in the early 1990s. Last, aggregate mortgage debt tends to move in concert with housing aggregates: as prices and sales rise, so too does debt.

This paper has three primary objectives. First, I seek to explain the previous stylized facts using a quantitative macroeconomic model of the U.S. economy that pays careful attention to some of the unique features of the housing and mortgage markets. Along the way, the model makes substantial progress in explaining other aspects of housing dynamics that continue to confound. Second, I investigate the degree to which two unique features of the housing and mortgage markets affect housing dynamics. Specifically, I look at the interaction of decentralized trade in the housing market—which makes housing an illiquid asset—and endogenous credit constraints that arise from the ability of homeowners to default on their mortgage obligations. Last, I consider the effects of a foreclosure reform that reduces debtor protections in an effort to discourage default.

In service of the first objective, I develop a two-sector macroeconomic model that features uninsurable, idiosyncratic earnings risk, aggregate shocks to productivity, directed search in the housing market, and long-term defaultable mortgage debt. Directed search makes trade in the housing market a decentralized activity that affords a degree of price setting power to buyers and sellers. Specifically, buyers can choose which size and price of house they want to search for, while sellers can choose the price at which to attempt to sell their houses. As a result, equilibrium does not determine a unique market clearing price but rather an endogenous distribution of market tightnesses (and thus trading probabilities) corresponding to the range of submarkets for each house size and price combination.

Given the presence of aggregate shocks and the nondegenerate, time-varying distribution of agents over individual wealth, debt, and income states, solving such a model could easily prove completely intractable. However, I extend the novel approach developed in Hedlund (2015) that establishes *block recursivity* in the housing market, which allows me to use the time path of one sufficient statistic—the shadow housing price—to calculate the dynamics of the entire distribution of house prices and trading probabilities. The introduction of one-period-lived real estate agents who passively intermediate trades between buyers and sellers allows me to obtain this result by following similar reasoning to that in Menzio and Shi (2010). This modeling innovation makes it possible to integrate housing markets with search frictions into an otherwise rich heterogeneous agent setting.

Beyond this important theoretical contribution, the model proves quite successful quantitatively in matching the above stylized facts on the dynamics of house prices, sales, residential investment, months supply, foreclosures, and household portfolios.

Notably, the model generates co-movements and volatilities of house prices, existing sales, and months supply almost identical to those in the United States from 1975 to 2010. I should stress that the model calibration targets only first moments of the U.S. economy, so the success of the model in matching these dynamics arises solely from its various amplification and propagation mechanisms.

Some of these mechanisms should appear familiar. In the model, shocks to productivity generate fluctuations in household income and equilibrium interest rates. During good economic times, households respond by increasing their consumption and their demand for housing. The increased demand for housing, combined with partially inelastic construction of houses, generates a boom in house prices and sales. The reverse chain of events occurs during downturns. In line with recent research by, among others, Head, Lloyd-Ellis, and Sun (2014) and Díaz and Jerez (2013), the introduction of search frictions propagates the effects of economic shocks across time. Similarly, as in Stein (1995), credit constraints in the mortgage market magnify the effect of income shocks.

This paper makes several important strides forward by showing the importance of *jointly* considering search frictions and *endogenous* credit constraints. First, the interaction between the two generates liquidity spirals á la Brunnermeier and Pedersen (2009), where movements in the degree of housing market liquidity—as measured by the probability of trade—and in the degree of mortgage market liquidity—as measured by default spreads priced into new mortgages—reinforce each other. As first identified by Hedlund (2015), search frictions create substantial selling risk for homeowners. During housing downturns, homeowners must lower their price to avoid long selling delays. However, homeowners with large mortgages find themselves debt-constrained and forced to set a high price. As a result, heavily indebted homeowners may fail to quickly sell their house in the event of financial necessity, causing many of them to end up in foreclosure. The wave of mortgage defaults causes a flood of foreclosure properties to depress the housing market. To make matters worse, banks anticipate the heightened foreclosure risk during times of low house prices and liquidity and respond by pricing higher default premia into new mortgages. This chain of events cascades into a vicious cycle of decreasing prices, lower selling probabilities, higher foreclosures, and tighter credit. The reverse happens in booms. I quantify the impact of these liquidity spirals and conclude that they contribute an additional 20% volatility to house prices and 27% volatility to residential investment.

The interaction of search frictions and endogenous credit also helps explain the prolonged, asymmetric nature of housing cycles. By delaying trades, search frictions spread out the impact of economic shocks on housing. Therefore, housing booms tend to evolve gradually and exhibit price momentum, as discussed in Case and Shiller (1989) and recently in Head, Lloyd-Ellis, and Sun (2014). However, the evolution of housing busts depends largely on their severity. During mild downturns, downward price stickiness emerges from a reluctance of homeowners to lower their price because they expect housing to rebound and because they took out long-term mortgages during more favorable conditions. However, after a post-boom large productivity drop, a spike in foreclosures and distressed sales contributes to a precipitous drop in house prices, followed by a prolonged decline drawn out by debt overhang. These scenarios reflect the shallow U.S. housing bust in the early 1990s and the recent sharp downturn, respectively.

Last, I consider the effects of a foreclosure reform that makes all mortgages legally as well as *effectively* full recourse. In particular, I allow banks to *costlessly* initiate deficiency judgments and seize up to 90% of the assets of foreclosed borrowers whose houses do not cover the full balance of their mortgage. I show that such a reform dramatically alters housing and foreclosure dynamics, with house price and residential investment volatilities dropping by 12% and 17%, respectively, and existing sales volatility *increasing* by over 38%. Furthermore, fluctuations in months supply drop by over 85% and foreclosures essentially disappear. Less cyclical movement in credit constraints and fewer high leverage borrowers prevent liquidity spirals from emerging, which explains much of the change in dynamics. However, even without liquidity spirals, the economy with recourse mortgages still generates protracted booms and busts.

1.1 *Related literature*

This paper makes substantial theoretical and quantitative contributions to the modeling and understanding of housing market movements. In doing so, I build upon multiple areas of related research. One strand of the literature, including seminal papers by Stein (1995) and Ortalo-Magné and Rady (2006), establishes how credit constraints magnify income shocks and amplify house price movements. Even so, the literature has struggled to develop housing models that produce sufficient house price volatility. Davis and Heathcote (2005) make one of the earliest attempts and successfully generate sufficient volatility in residential investment, but not in house prices.

Several recent papers model housing in an incomplete markets setting, such as Iacoviello and Pavan (2013), Kiyotaki, Michaelides, and Nikolov (2011), Ríos-Rull and Sánchez-Marcos (2008), Chu (2013), and Favilukis, Ludvigson, and Van Nieuwerburgh (2013). The latter two, along with Kahn (2009), make progress in generating volatile house prices and highlight the importance of inelastic construction, time-varying risk premia, and inelastic substitution between housing and consumption, respectively. However, none of the previous papers addresses all of the stylized facts described in the Introduction, including notably the strong countercyclicality of months supply and foreclosures.

Another strand of the literature deviates from the Walrasian framework by developing search models of housing, as in early papers by Wheaton (1990) and Krainer (2001). Most related to my work here are recent contributions by Novy-Marx (2009), Burnside, Eichenbaum, and Rebelo (2014), Caplin and Leahy (2011), Díaz and Jerez (2013), and Head, Lloyd-Ellis, and Sun (2014). Novy-Marx (2009) and Díaz and Jerez (2013) both show how search frictions magnify shocks to fundamentals, with Díaz and Jerez (2013) emphasizing the importance of directed search, rather than random search, in housing markets. Burnside, Eichenbaum, and Rebelo (2014) introduce learning and social dynamics to generate housing booms that are only sometimes followed by busts. Head, Lloyd-Ellis, and Sun (2014) generate house price momentum in a city-level model of housing with free entry of buyers. I add to this literature by integrating a frictional, decentralized housing market into a fully closed production economy with imperfect credit markets and substantial household heterogeneity, which allows me to simultaneously address all of the major stylized facts on housing, debt, and foreclosure dynamics.

My paper also fits into the literature on mortgage default. Mitman (2014), Hintermaier and Koeniger (2011), and Jeske, Krueger, and Mitman (2013) study foreclosures in an environment with one-period mortgages, which forces homeowners to refinance each period. Chatterjee and Eyigungor (2015), Corbae and Quintin (2015), and Garriga and Schlagenhauf (2009) analyze foreclosures in steady state and transition with long-term mortgage contracts. I extend this work by studying foreclosure dynamics with long-term mortgages and aggregate uncertainty.

Last, my paper complements Menzio and Shi (2010) and Hedlund (2015) by utilizing block recursivity to develop a directed search model of housing with two-sided heterogeneity and computationally tractable aggregate dynamics. A supplementary appendix with additional figures, calibration and computation details, and replication files can be found on the journal website, http://qeconomics.org/supp/483/supplement.pdf and http://qeconomics.org/supp/483/code_and_data.zip.

2. The model

2.1 *Households*

Households inelastically supply one unit of time to the labor market and are paid wage w per unit of stochastic labor efficiency $e \cdot s$, where $s \in S$ follows a finite Markov chain with transitions $\pi_s(s'|s)$ and e is drawn from the cumulative distribution function $F(e)$ with compact support $E \subset \mathbb{R}_+$. Households initially draw s from the invariant distribution $\Pi_s(s)$.

Households derive utility from composite consumption c and housing services c_h. Homeowners with house size $h \in H = \{\underline{h}, h_2, h_3\}$ receive a dividend $c_h = h$ of housing services each period, while renters purchase housing services $c_h \in [0, \underline{h}]$ from a competitive spot market at price r_h (relative to the numeraire consumption good). All homeowners are owner–occupiers and can only own one house at a time.

Households save by purchasing one-period bonds with price $q_b \in (0, 1)$ from financial intermediaries. Homeowners also have the option to borrow against their house with mortgage debt. I detail the structure of mortgage contracts in the financial intermediaries section.

2.2 *Consumption good sector*

Consumption good firms operate a constant returns to scale production function using capital K_c and labor N_c to produce composite consumption

$$Y_c = z_c F_c(K_c, N_c).$$

Total factor productivity z_c follows a finite state Markov chain with transition probabilities $\pi_z(z_c'|z_c)$. Firms rent capital from financial intermediaries at rental rate r and pay wage w per unit of labor efficiency. Output can be consumed, added to the capital stock, or used to build new housing. Let $\mathbf{Z}$ denote the aggregate state of the economy, which I describe in detail later.

The profit maximization conditions of the composite good firm are

$$r(\mathbf{Z}) = z_c \frac{\partial F_c(K_c(\mathbf{Z}, N_c(\mathbf{Z}))}{\partial K_c}, \tag{1}$$

$$w(\mathbf{Z}) = z_c \frac{\partial F_c\big(K_c(\mathbf{Z}), N_c(\mathbf{Z})\big)}{\partial N_c}. \tag{2}$$

2.2.1 *Housing services for renters* Landlords convert the consumption good into housing services at the rate A_h using a linear, reversible technology and sell these housing services competitively at price r_h.

The profit maximization condition of landlords is

$$r_h = \frac{1}{A_h}. \tag{3}$$

2.3 *Construction sector*

Construction firms operate a constant returns to scale production function using land/permits L, structures S_h, and labor N_h to produce new housing

$$Y_h = F_h(L, S_h, N_h).$$

Firms purchase new land/permits from the government at price p_l, pay wage w per unit of labor efficiency, and purchase structures S_h from the consumption good sector. The government supplies a fixed amount $\bar{L} > 0$ of new land/permits each period, and all revenues go to unproductive government spending. Construction firms sell new houses in discrete sizes $h \in H$ directly to real estate firms at price p_h and do not experience any building delays.

Individual houses depreciate stochastically with probability δ_h.[2] In the aggregate, the housing stock evolves according to

$$H' = (1 - \delta_h)H + Y_h'.$$

The profit maximization conditions of construction firms are

$$p_l(\mathbf{Z}) = p_h(\mathbf{Z}) \frac{\partial F_h\big(L(\mathbf{Z}), S_h(\mathbf{Z}), N_h(\mathbf{Z})\big)}{\partial L}, \tag{4}$$

$$1 = p_h(\mathbf{Z}) \frac{\partial F_h\big(L(\mathbf{Z}), S_h(\mathbf{Z}), N_h(\mathbf{Z})\big)}{\partial S_h}, \tag{5}$$

[2]Complete depreciation averts the need to deal with situations where mortgaged homeowners suddenly find themselves under water because a portion of their house depreciates. As I discuss later, I assume complete mortgage forgiveness in the low probability event that a house depreciates.

$$w(\mathbf{Z}) = p_h(\mathbf{Z}) \frac{\partial F_h\big(L(\mathbf{Z}), S_h(\mathbf{Z}), N_h(\mathbf{Z})\big)}{\partial N_h}. \tag{6}$$

2.4 *Real estate sector*

The real estate sector is populated by a continuum of real estate firms that facilitate housing trades between buyers and sellers. In the absence of a centralized market, buyers and sellers match bilaterally with real estate agents in an environment with search frictions. First, sellers attempt to match with real estate agents to sell their house. Next, buyers attempt to match with real estate agents to purchase a house recently sold by a seller. Real estate firms simply act as conduits to transfer houses from sellers to buyers, but greatly improve the tractability of the model, as I discuss later.

2.4.1 *Decentralized house selling* Sellers direct their search to real estate agents by choosing a selling price $x_s \geq 0$ for their house $h \in H$. Formally, sellers choose x_s to enter submarket $(x_s, h) \in \mathbb{R}_+ \times H$. Sellers commit to the selling price, conditional on successfully matching with a real estate agent, and pay utility cost ξ if they fail to match.[3] Real estate firms hire a continuum $\Omega_s(x_s, h)$ of real estate agents to enter each submarket at cost $\kappa_s h$. The ratio of real estate agents to sellers in submarket (x_s, h), or market tightness, is $\theta_s(x_s, h) \geq 0$, and is determined in equilibrium.[4] A seller in submarket (x_s, h) successfully matches with a real estate agent with probability $p_s(\theta_s(x_s, h))$, while a real estate agent in submarket (x_s, h) successfully matches with a seller with probability $\alpha_s(\theta_s(x_s, h)) = \frac{p_s(\theta_s(x_s,h))}{\theta_s(x_s,h)}$. The function $p_s: \mathbb{R}_+ \to [0, 1]$ is continuous and strictly increasing with $p_s(0) = 0$, and α_s is strictly decreasing. Real estate agents may match with multiple sellers if $\alpha_s > 1$, but sellers always match with at most one real estate agent. By the law of large numbers, real estate firms know exactly how many matches agents will have with sellers, and to ensure that real estate firms are passive market participants, I do not allow them to hold housing inventories. Agents and sellers take $\theta_s(x_s, h)$ parametrically.

2.4.2 *Decentralized house buying* Buyers direct their search to real estate agents by choosing a submarket (x_b, h) with purchase price $x_b \geq 0$ and house size $h \in H$. Buyers match with a real estate agent with probability $p_b(\theta_b(x_b, h))$ and agents match with a buyer with probability $\alpha_b(\theta_b(x_b, h)) = \frac{p_b(\theta_b(x_b,h))}{\theta_b(x_b,h)}$, where $\theta_b(x_b, h)$ is the market tightness. The functions p_b and α_b have the same properties as p_s and α_s, respectively. Successful buyers immediately move into their house, while unsuccessful buyers remain as renters until the next period. Real estate firms hire a continuum $\Omega_b(x_b, h)$ of real estate agents to enter each submarket at cost $\kappa_b h$ per agent. Real estate agents and buyers take $\theta_b(x_b, h)$ parametrically.

[3]The utility cost discourages homeowners who are nearly indifferent about selling from posting a selling price that causes their house to take extremely long to sell.

[4]In unvisited submarkets, $\theta_s(x_s, h)$ is an out-of-equilibrium belief that helps determine equilibrium behavior.

2.4.3 *Market tightnesses* Real estate firms purchase new housing Y_h and hire agents Ω_s and Ω_b to intermediate trades between buyers and sellers, solving

$$\begin{aligned} \max_{\substack{Y_h\geq 0, \Omega_s(x_s,h)\geq 0,\\ \Omega_b(x_b,h)\geq 0}} & \int \left[-\kappa_s h + \alpha_s\big(\theta_s(x_s, h; \mathbf{Z})\big)(-x_s)\right]\Omega_s(dx_s, dh) - p_h(\mathbf{Z})Y_h \\ & + \int \left[-\kappa_b h + \alpha_b\big(\theta_b(x_b, h; \mathbf{Z})\big)x_b\right]\Omega_b(dx_b, dh) \\ & \text{subject to} \\ & Y_h + \int h\alpha_s\big(\theta_s(x_s, h; \mathbf{Z})\big)\Omega_s(dx_s, dh) \geq \int h\alpha_b\big(\theta_b(x_b, h; \mathbf{Z})\big)\Omega_b(dx_b, dh), \end{aligned} \tag{7}$$

where the constraint (with multiplier $\mu(\mathbf{Z})$) reflects the fact that all houses the real estate firm sells to buyers it must first acquire from sellers.

Profit maximization implies $\mu(\mathbf{Z}) = p_h(\mathbf{Z})$ and that market tightnesses satisfy

$$\begin{aligned} & \kappa_b h \geq \alpha_b\big(\theta_b(x_b, h; \mathbf{Z})\big)\big(x_b - p_h(\mathbf{Z})h\big) \quad \text{and} \\ & \theta_b(x_b, h; \mathbf{Z}) \geq 0 \quad \text{with comp. slackness,} \end{aligned} \tag{8}$$

$$\begin{aligned} & \kappa_s h \geq \alpha_s\big(\theta_s(x_s, h; \mathbf{Z})\big)\big(p_h(\mathbf{Z})h - x_s\big) \quad \text{and} \\ & \theta_s(x_s, h; \mathbf{Z}) \geq 0 \quad \text{with comp. slackness.} \end{aligned} \tag{9}$$

2.5 *Financial sector*

Intermediaries trade bonds $b' \in B > 0$ and mortgages $m' \in M > 0$ with households, accumulate capital to rent to firms, and manage their stock of repossessed foreclosure housing. Capital evolves according to

$$K' = (1 - \delta_c)K + I.$$

Intermediaries have access to international bond financing at interest rate i, although I focus on the closed economy case (zero net supply).

2.5.1 *Mortgages* Borrowers who take out a mortgage of size m' receive $q_m^0 m'$ at origination, where $q_m^0 \in (0, 1)$ is the mortgage price. Perfect competition partitions the mortgage market by loan size and borrower characteristics, and causes intermediaries to earn zero expected profits loan-by-loan.[5] Therefore, mortgage prices q_m^0 depend on the initial balance m', the borrower's house size h, the aggregate state of the economy $\mathbf{Z}$, and the borrower's initial savings b' and persistent labor efficiency component s.

[5]The government distributes all ex post profits/losses to households through a proportional wealth tax/subsidy τ. This arrangement bypasses the need to explicitly assign ownership of intermediaries. Instead, intermediaries are risk-neutral entities that discount the future at the international bond rate i.

To proxy for the array of mortgage instruments (second mortgages, home equity lines of credit, etc.) that households can use to manage their total mortgage debt, I allow borrowers to repay their loan according to a flexible repayment schedule. Specifically, borrowers choose how quickly to pay down principal, while the remaining balance accrues interest at rate r_m. Borrowers can only increase their mortgage debt by paying off their existing balance and taking out a new loan.

Intermediaries incur proportional origination costs ζ and servicing costs ϕ over the life of each mortgage. Additionally, intermediaries face two sources of non-repayment risk. First, if a borrower's house stochastically depreciates, the intermediary absorbs the entire mortgage loss without any penalty for the borrower.[6] Second, a borrower may choose to default, which causes the intermediary to initiate foreclosure proceedings.

Intermediaries price the origination cost and default risk into q_m^0, while the servicing cost and depreciation risk affect the interest rate r_m. By front-loading all default risk into the initial mortgage price, intermediaries exhibit one-sided commitment and do not subject households to mortgage repricing risk. This modeling approach for mortgages greatly simplifies computation by reducing the mortgage state to only the loan balance.

2.5.2 *Consequences of mortgage default* I model a single legal environment for mortgage default, although actual laws vary by state. Mitman (2014) explores this legal variation more in-depth.

In the model, mortgage default causes the following chain of events:

1. The borrower's mortgage debt is erased and a foreclosure filing is placed on the borrower's credit record ($f = 1$). The borrower's other financial assets are left intact.

2. The intermediary repossesses the borrower's house as real estate owned (REO) property and tries to sell it in the decentralized selling market.

   (a) The intermediary has reduced search efficiency $\lambda \in (0, 1)$ and, upon successful sale, loses a fraction χ of the sale price.[7]

   (b) The intermediary absorbs all mortgage losses but must pass along any potential profits from the foreclosure sale to the borrower.

3. Households with $f = 1$ lose access to the mortgage market,[8] and the foreclosure flag stays on their record at the beginning of the next period with probability $\gamma_f \in (0, 1)$.[9]

2.5.3 *Mortgage prices* Each period, intermediaries choose capital K', issue bonds B' to households, and originate $n_m(m', b', h, s)$ mortgages of type (m', b', h, s). The intermediary discounts period-t cash flows at the international bond interest rate i. Long-duration assets on the intermediary's balance sheet—namely, vintage mortgages and

[6] This assumption prevents the model from generating artificially high foreclosure rates.

[7] This proportional loss accounts for various foreclosure costs and foreclosure property degradation.

[8] Fannie Mae and Freddie Mac do not purchase mortgages issued to borrowers with recent foreclosure filings, making it much less appealing to lend to these borrowers.

[9] Foreclosure filings stay on a borrower's credit record for a finite number of years.

REO inventories—are priced-to-market. Therefore, intermediaries effectively sell their vintage mortgages and REO inventories at the beginning of the period, distribute ex post losses or gains, and then repurchase their REO inventories and vintage mortgages at the end of the period.

Intermediary profit maximization implies

$$q_b(\mathbf{Z}) = \frac{1}{1+i(\mathbf{Z})} = \frac{1}{1-\delta_c+\mathbb{E}r(\mathbf{Z}')}, \tag{10}$$

$$q_m(\mathbf{Z}) \equiv \frac{1}{1+r_m(\mathbf{Z})} = \frac{1-\delta_h}{1+\phi} q_b(\mathbf{Z}), \tag{11}$$

with next period's capital equaling the end-of-period sum of bond issuances minus the value of unsold REO inventories and new and vintage mortgages.

Mortgage prices satisfy the recursive relationship

$$\begin{aligned} &q_m^0(m', b', h, s; \mathbf{Z}) \\ &\quad = \frac{q_m(\mathbf{Z})}{(1+\zeta)} \mathbb{E}\Big\{ p_s\big(\theta_s(x_s^{*\prime}, h; \mathbf{Z}')\big) + \big[1 - p_s\big(\theta_s(x_s^{*\prime}, h; \mathbf{Z}')\big)\big] \\ &\quad \times \bigg[d^{*\prime} \min\Big\{1, \frac{J_{\text{REO}}(h; \mathbf{Z}')}{m'}\Big\} + \big(1 - d^{*\prime}\big) \\ &\quad \times \bigg(\frac{\overbrace{m' - (1+\phi) q_m(\mathbf{Z}') m^{*\prime\prime} \mathbf{1}_{[m^{*\prime\prime} \le m']}}^{\text{payment}-\text{servicing cost}} + \overbrace{\Pi\big(m^{*\prime\prime}, b^{*\prime\prime}, h, s'; \mathbf{Z}'\big) \mathbf{1}_{[m^{*\prime\prime} \le m']}}^{\text{continuation value}}}{m'} \bigg) \bigg] \Big\}, \\ &\mathbf{Z}' = G(\mathbf{Z}, z_c'), \end{aligned} \tag{12}$$

where $x_s^{*\prime}$, $m^{*\prime\prime}$, $b^{*\prime\prime}$, and $d^{*\prime}$, stand in for the homeowner's respective next period choices of selling price, new mortgage balance, bonds, and whether to default. Also, J_{REO} is the intermediary's value function for repossessing the borrower's house, G is the aggregate law of motion, and Π is the continuation value of the mortgage,

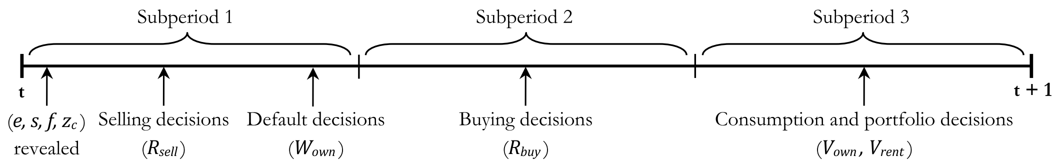
$$\Pi\big(m^{*\prime\prime}, b^{*\prime\prime}, h, s'; \mathbf{Z}'\big) = q_m^0\big(m^{*\prime\prime}, b^{*\prime\prime}, h, s'; \mathbf{Z}'\big)(1+\zeta)(1+\phi) m^{*\prime\prime}.$$

Foreclosure sales Intermediaries sell their REO inventories by choosing a submarket (x_s, h). The value to intermediaries of a repossessed house satisfies

$$\begin{aligned} &J_{\text{REO}}(h; \mathbf{Z}) = R_{\text{REO}}(h; \mathbf{Z}) + (1-\delta_h) q_b(\mathbf{Z}) \mathbb{E} J_{\text{REO}}\big(h; \mathbf{Z}'\big), \\ &R_{\text{REO}}(h; \mathbf{Z}) \\ &\quad = \max\Big\{0, \max_{x_s \ge 0} \lambda p_s\big(\theta_s(x_s, h; \mathbf{Z})\big)\big[(1-\chi) x_s - (1-\delta_h) q_b(\mathbf{Z}) \mathbb{E} J_{\text{REO}}\big(h; \mathbf{Z}'\big)\big]\Big\}, \\ &\mathbf{Z}' = G(\mathbf{Z}, z_c'). \end{aligned} \tag{13}$$

2.6 *Household problem*

2.6.1 *Timeline*



Each period consists of three subperiods. Homeowners and renters begin the period by learning their cash at hand $y = w(\mathbf{Z})e \cdot s + b$ (where b is their choice last period of bonds), their persistent labor efficiency shock s, and their credit flag $f \in \{0, 1\}$. In addition, the individual state of homeowners includes the house size h and the mortgage balance m.

The aggregate state $\mathbf{Z} = (z_c, \Phi, K, \{H_{\text{REO}}(h)\}_h)$ consists of the productivity shock z_c, the distribution Φ of homeowners and renters over individual states, the capital stock K, and the REO housing stock $\{H_{\text{REO}}(h)\}_h$. Now I work through the household value functions, starting at the end of the period and moving backward.

Consumption/saving End of period homeowner expenditures consist of the numeraire consumption good, bond purchases, and mortgage payments. The budget constraint is

$$c + q_b(\mathbf{Z})b' + \overbrace{m - \widetilde{q_m}\big(m', b', h, s; \mathbf{Z}\big)m'}^{\text{mortgage payment}} \leq y,$$

where $\widetilde{q_m}(\cdot; \mathbf{Z}) = q_m(\mathbf{Z})$ if owners choose $m' \leq m$ and $\widetilde{q_m}(\cdot; \mathbf{Z}) = q_m^0(\cdot; \mathbf{Z})$ otherwise.

Homeowners with good credit are represented as

$$\begin{aligned} &V_{\text{own}}(y, m, h, s, 0; \mathbf{Z}) \\ &\quad = \max_{m', b', c \geq 0} u(c, h) + \beta \mathbb{E}\big[(1 - \delta_h)(W_{\text{own}} + R_{\text{sell}})\big(y', m', h, s', 0; \mathbf{Z}'\big) \\ &\qquad + \delta_h (V_{\text{rent}} + R_{\text{buy}})\big(y', s', 0; \mathbf{Z}'\big)\big] \\ &\text{subject to} \\ &c + q_b(\mathbf{Z})b' + m - \widetilde{q_m}\big(m', b', h, s; \mathbf{Z}\big)m' \leq y, \\ &q_m^0\big(m', b', h, s; \mathbf{Z}\big)m' \mathbf{1}_{[m' > m]} \leq p_h(\mathbf{Z}), \\ &y' = \big(1 - \tau(\mathbf{Z}')\big)\big(w(\mathbf{Z}')e's' + b'\big), \\ &\mathbf{Z}' = G\big(\mathbf{Z}, z_c'\big). \end{aligned} \tag{14}$$

Homeowners with bad credit are represented as

$$\begin{aligned} &V_{\text{own}}(y, 0, h, s, 1; \mathbf{Z}) \\ &\quad = \max_{b', c \geq 0} u(c, h) + \beta \mathbb{E}\big[(1 - \delta_h)(W_{\text{own}} + R_{\text{sell}})\big(y', 0, h, s', f'; \mathbf{Z}'\big) \\ &\qquad + \delta_h (V_{\text{rent}} + R_{\text{buy}})\big(y', s', f'; \mathbf{Z}'\big)\big] \end{aligned}$$

$$\text{subject to} \tag{15}$$
$$c + q_b(\mathbf{Z})b' \le y,$$
$$y' = (1 - \tau(\mathbf{Z}'))(w(\mathbf{Z}')e's' + b'),$$
$$\mathbf{Z}' = G(\mathbf{Z}, z_c').$$

Renters replace mortgage payments with period-by-period purchases of housing services:

$$c + r_h c_h + q_b(\mathbf{Z})b' \le y.$$

Renters with good credit are represented as

$$V_{\text{rent}}(y, s, 0; \mathbf{Z}) = \max_{b', c \ge 0, c_h \in [0, \underline{h}]} u(c, c_h) + \beta \mathbb{E}\big[(V_{\text{rent}} + R_{\text{buy}})(y', s', 0; \mathbf{Z}')\big]$$
subject to
$$c + r_h c_h + q_b(\mathbf{Z})b' \le y, \tag{16}$$
$$y' = (1 - \tau(\mathbf{Z}'))(w(\mathbf{Z}')e's' + b'),$$
$$\mathbf{Z}' = G(\mathbf{Z}, z_c').$$

Renters with bad credit are represented as

$$V_{\text{rent}}(y, s, 1; \mathbf{Z}) = \max_{b', c \ge 0, c_h \in [0, \underline{h}]} u(c, c_h) + \beta \mathbb{E}\big[(V_{\text{rent}} + R_{\text{buy}})(y', s', f'; \mathbf{Z}')\big]$$
subject to
$$c + r_h c_h + q_b(\mathbf{Z})b' \le y, \tag{17}$$
$$y' = (1 - \tau(\mathbf{Z}'))(w(\mathbf{Z}')e's' + b'),$$
$$\mathbf{Z}' = G(\mathbf{Z}, z_c').$$

House buying Renters (which includes successful home sellers from subperiod 1) direct their search to a submarket (x_b, h) of their choice. Renters with bad credit are bound by the constraint $y - x_b \ge 0$, while renters with good credit are bound by the constraint $y - x_b \ge \underline{y}(h, s; \mathbf{Z})$, where $\underline{y} < 0$ reflects the ability of new buyers to take out a mortgage in subperiod 3. The option value $R_{\text{REO}}(y, s, f; \mathbf{Z})$ to attempting to buy is

$$\begin{aligned} R_{\text{buy}}(y, s, 0; \mathbf{Z}) = \max\Big\{0, \max_{\substack{h \in H, \\ x_b \le y - \underline{y}}} p_b(\theta_b(x_b, h; \mathbf{Z})) \\ \times \big[V_{\text{own}}(y - x_b, 0, h, s, 0; \mathbf{Z}) - V_{\text{rent}}(y, s, 0; \mathbf{Z})\big]\Big\}, \end{aligned} \tag{18}$$

$$\begin{aligned} R_{\text{buy}}(y, s, 1; \mathbf{Z}) = \max\Big\{0, \max_{\substack{h \in H, \\ x_b \le y}} p_b(\theta_b(x_b, h; \mathbf{Z})) \\ \times \big[V_{\text{own}}(y - x_b, 0, h, s, 1; \mathbf{Z}) - V_{\text{rent}}(y, s, 1; \mathbf{Z})\big]\Big\}. \end{aligned} \tag{19}$$

Mortgage default The value function for a homeowner deciding whether to default is

$$\begin{aligned} & W_{\text{own}}(y, m, h, s, 0; \mathbf{Z}) \\ & \quad = \max\bigl\{(V_{\text{rent}} + R_{\text{buy}})\bigl(y + \max\bigl\{0, J_{\text{REO}}(h; \mathbf{Z}) - m\bigr\}, s, 1; \mathbf{Z}\bigr), \\ & \qquad V_{\text{own}}(y, m, h, s, 0; \mathbf{Z})\bigr\}. \end{aligned} \tag{20}$$

For homeowners with bad credit and no mortgage,

$$W_{\text{own}}(y, 0, h, s, 1; \mathbf{Z}) = V_{\text{own}}(y, 0, h, s, 1; \mathbf{Z}). \tag{21}$$

House selling Homeowners in subperiod 1 decide whether to try to sell their house. For owners of house size h who want to sell, they choose a list price x_s and direct their search to submarket (x_s, h). Their value functions are

$$\begin{aligned} & R_{\text{sell}}(y, m, h, s, 0; \mathbf{Z}) \\ & \quad = \max\Bigl\{0, \max_{y+x_s \geq m} p_s\bigl(\theta_s(x_s, h; \mathbf{Z})\bigr)\bigl[(V_{\text{rent}} + R_{\text{buy}})(y + x_s - m, s, 0; \mathbf{Z}) \\ & \qquad - W_{\text{own}}(y, m, h, s, 0; \mathbf{Z})\bigr] - \bigl[1 - p_s\bigl(\theta_s(x_s, h; \mathbf{Z})\bigr)\bigr]\xi\Bigr\}, \end{aligned} \tag{22}$$

$$\begin{aligned} & R_{\text{sell}}(y, m, h, s, 1; \mathbf{Z}) \\ & \quad = \max\Bigl\{0, \max_{x_s} p_s\bigl(\theta_s(x_s, h; \mathbf{Z})\bigr)\bigl[(V_{\text{rent}} + R_{\text{buy}})(y + x_s, s, 1; \mathbf{Z}) \\ & \qquad - W_{\text{own}}(y, m, h, s, 1; \mathbf{Z})\bigr] - \bigl[1 - p_s\bigl(\theta_s(x_s, h; \mathbf{Z})\bigr)\bigr]\xi\Bigr\}. \end{aligned} \tag{23}$$

Note that sellers with mortgage debt m must choose a price x_s sufficiently high to pay off their debt upon sale, that is, $y + x_s \geq m$.[10]

2.7 *Equilibrium*

2.7.1 *Block recursivity in the housing market* This paper develops a notion of *block recursivity* parallel to that in Menzio and Shi (2010) that applies to the housing market with aggregate uncertainty. At first glance, submarket tightnesses $\theta_s(x_s, h; \mathbf{Z})$ and $\theta_b(x_b, h; \mathbf{Z})$ appear to be functions of the entire aggregate state $\mathbf{Z}$, which is an infinite dimensional object that includes the distribution of households. However, (8) and (9) show that active submarkets ($\theta > 0$) do not depend directly on the distribution of household characteristics, but only on p_h:

$$\theta_b\bigl(x_b, h; p_h(\mathbf{Z})\bigr) = \alpha_b^{-1}\left(\frac{\kappa_b h}{x_b - p_h(\mathbf{Z})h}\right), \tag{24}$$

$$\theta_s\bigl(x_s, h; p_h(\mathbf{Z})\bigr) = \alpha_s^{-1}\left(\frac{\kappa_s h}{p_h(\mathbf{Z})h - x_s}\right). \tag{25}$$

[10]There are no short sales. For a variety of reasons, short sales are historically rare in the data.

In short, the shadow housing price p_h acts as a sufficient statistic for $\mathbf{Z}$ when calculating submarket tightnesses, which greatly improves computational tractability. As explained more carefully by Hedlund (2015), block recursivity arises in this environment because terms of trade are set ahead of time (search is *directed*) and because of free entry by real estate agents. These two ingredients combine in such a way as to make the endogenous distribution of households across submarkets irrelevant beyond its impact on p_h.

2.7.2 *Determining the shadow housing price* The shadow housing price p_h equates two Walrasian-like demand and supply equations. Housing supply $S_h(p_h;\mathbf{Z})$ equals the sum of new housing and existing houses sold by homeowners and intermediaries,

$$\begin{aligned} S_h(p_h;\mathbf{Z}) &= Y_h(p_h;\mathbf{Z}) + S_{\text{REO}}(p_h;\mathbf{Z}) \\ &\quad + \int hp_s\big(\theta_s\big(x_s^*, h;\, p_h\big)\big)\Phi_{\text{own}}(dy, dm, dh, ds, df), \end{aligned}$$

where the first term is new housing, the second term is REO housing, and the third term is homeowner housing.

Housing demand $D_h(p_h;\mathbf{Z})$ equals housing purchased by matched buyers:[11]

$$D_h(p_h;\mathbf{Z}) = \int h^* p_b\big(\theta_b\big(x_b^*, h^*;\, p_h\big)\big)\Phi_{\text{rent}}(dy, ds, df).$$

The equilibrium shadow housing price $p_h(\mathbf{Z})$ solves

$$D_h\big(p_h(\mathbf{Z});\mathbf{Z}\big) = S_h\big(p_h(\mathbf{Z});\mathbf{Z}\big). \tag{26}$$

2.7.3 *Definition of equilibrium* A recursive equilibrium consists of household value and policy functions, production firm policies, intermediary value and policy functions, market tightnesses, a shadow housing price, and prices for production factors, housing services, bonds, and mortgages, in addition to an aggregate law of motion. These elements must solve the household, firm, and intermediary optimization problems and must equilibrate the markets for housing, land, labor, capital, international bonds, and the consumption good. I solve the equilibrium using a hybrid of methods based on Krusell and Smith (1998) and those methods used in the literature on equilibrium default. The detailed equilibrium definition and computational algorithm are given in the Appendix.

3. Model calibration

I calibrate the steady state of the model to match selected macroeconomic data from the 1990s, thus avoiding skewing the calibration with the recent extraordinary housing boom–bust and the Great Recession. First, I choose some parameters from the literature or from a priori information. I jointly calibrate the remaining parameters.

[11] Equivalently, housing supply equals the left side of the real estate firm's constraint while housing demand equals the right side.

3.1 *Model specification*

3.1.1 *Households*

Preferences Households have constant elasticity of substitution utility with constant relative risk aversion:

$$u(c, c_h) = \frac{\left(\left[\omega c^{(\nu-1)/\nu} + (1-\omega)c_h^{(\nu-1)/\nu}\right]^{\nu/(\nu-1)}\right)^{1-\sigma}}{1-\sigma}.$$

I follow Kahn (2009) and Flavin and Nakagawa (2008) and set the intratemporal elasticity of substitution to $\nu = 0.13$.[12] I determine the discount factor β and risk aversion σ jointly.

Labor efficiency Log labor efficiency, $\ln(e \cdot s) = \ln(s) + \ln(e)$, follows

$$\ln(s') = \rho_s \ln(s) + \varepsilon',$$
$$\varepsilon' \sim \mathcal{N}(0, \sigma_\varepsilon^2),$$
$$\ln(e) \sim \mathcal{N}(0, \sigma_e^2).$$

I calibrate ρ_s, σ_ε, and σ_e following Storesletten, Telmer, and Yaron (2004), with some modifications that I explain in the Appendix. Computationally, I truncate $\ln(e)$ and discretize $\ln(s)$ with a three-state Markov chain using the Rouwenhorst method.

3.1.2 *Production sectors*

I specify Cobb–Douglas production functions in both sectors:

$$Y_c = z_c A_c K^{\alpha_K} N_c^{1-\alpha_K}, \qquad Y_h = L^{\alpha_L}\left(S_h^{\alpha_S} N_h^{1-\alpha_S}\right)^{1-\alpha_L}.$$

I normalize mean quarterly earnings to 0.25 using A_c, and I set $\alpha_K = 0.26$, following Díaz and Luengo-Prado (2010). The shock z_c follows

$$\ln(z_c') = \rho_z \ln(z_c) + \varepsilon_z',$$
$$\varepsilon_z \sim \mathcal{N}(0, \sigma_{\varepsilon_z}^2),$$

with standard values $\rho_z = 0.95$ and $\sigma_{\varepsilon_z}^2 = 0.007$. I discretize z_c with a three-state Markov chain using the Rouwenhorst method.

In the construction sector, I follow Favilukis, Ludvigson, and Van Nieuwerburgh (2013) and set the structures share to $\alpha_S = 0.3$. I set the land share to $\alpha_L = 0.33$ based on data from the Lincoln Institute of Land Policy.[13] Following Harding, Rosenthal, and Sirmans (2007), I set $\delta_h = 0.00625$, which corresponds to a 2.5% annual housing depreciation rate. I normalize $\bar{L} = 1$ and determine the housing services technology A_h jointly.

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[12] See also Li, Liu, Yang, and Yao (2015). These papers find empirical evidence of a unit income elasticity for housing expenditures but a price elasticity substantially below 1.

[13] Available at http://www.lincolninst.edu/subcenters/land-values/price-and-quantity.asp.

3.1.3 *Real estate sector* I specify constant elasticity of substitution matching functions. Therefore, buying ($j = b$) and selling ($j = s$) trading probabilities are

$$p_j(\theta_j) = \min\left\{\frac{A_j\theta_j}{\left(1+\theta_j^{\gamma_j}\right)^{1/\gamma_j}}, 1\right\} \quad \text{and} \quad \alpha_j(\theta_j) = \frac{p_j(\theta_j)}{\theta_j}.$$

The Appendix gives the analytical characterization of trading probabilities for given p_h. I jointly calibrate A_j, κ_j, γ_j, and utility cost ξ.

3.1.4 *Financial sector* I set the mortgage origination cost to 2% ($\zeta = 0.02$), consistent with reports from the Federal Housing Finance Board of typical closing costs of 1%–3%.[14]

I set the servicing cost $\phi = 4.15 \times 10^{-5}$ to achieve a 2.65% spread between steady state mortgage interest rates $1 + r_m = \frac{(1+\phi)(1+i)}{1-\delta_h}$ and bond yields $1 + i$. The annual capital depreciation rate is 10%, implying quarterly $\delta_c = 0.025$.

3.1.5 *Foreclosures and legal environment* I set $\gamma_f = 0.95$ to give an expected credit flag duration of 5 years.[15] I jointly calibrate the REO sale loss χ and search efficiency λ.

3.2 *Joint calibration*

Following Hedlund (2015), I divide the targets of the joint calibration into three categories: macroeconomic aggregates, household financial data, and housing market data. The calibration is summarized in Table 1.

3.2.1 *Macroeconomic aggregates* I target a 15% housing services-to-GDP ratio and, following Díaz and Luengo-Prado (2010), a nonresidential capital-to-GDP ratio of 1.64.[16]

3.2.2 *Household financial data* I use the 1998 Survey of Consumer Finances to target selected asset and debt statistics. I target mean homeowner housing wealth relative to normalized earnings of 3.62 and mean mortgage debt, conditional on having a mortgage, of 2.03, using p_h to valuate housing wealth.

3.2.3 *Housing market data* I target a 64% home ownership rate, an annual foreclosure rate of 1.4%, an average foreclosure price discount of 22% as reported by Pennington-Cross (2006), an average foreclosure house selling time of 52 weeks, and mean buyer and seller search durations of 10 weeks and 17 weeks, respectively.[17] To calculate search durations, I assume that housing trades in period t occur uniformly between t and $t + 1$, as in Caplin and Leahy (2011). Trading after n periods corresponds to a search time of $(n + 0.5) \times 12$ weeks.

[14] Mortgage rates and fees can be found at http://www.fhfa.gov/Default.aspx?Page=252.

[15] Fannie Mae and Freddie Mac do not generally underwrite mortgages to borrowers with foreclosure records until after 5 years.

[16] Housing services in the model equal $r_h c_h$ for renters and $r_h h$ for homeowners.

[17] Sources: The Census Bureau, the National Delinquency Survey, and the National Association of Realtors. The foreclosure selling duration implicitly includes any legal delays.

Table 1. Model calibration.

Parameter	Value	Target Description	Target	Model
		Parameters determined independently		
Preferences				
ν	0.13	Intratemporal elasticity of substitution		
Stochastic labor endowment				
ρ_s	0.952	Autocorrelation of persistent shock		
σ_e	0.49	Standard deviation of transitory shock		
σ_ε	0.17	Standard deviation of persistent shock		
Production technologies				
ρ_z	0.95	Autocorrelation of technology shock		
$\sigma^2_{\varepsilon_z}$	0.007	Variance of technology shock		
α_K	0.26	Nonresidential capital share	26%	26%
α_L	0.33	Land share in construction	33%	33%
α_S	0.30	Residential structures share	30%	30%
δ_c	0.025	Annual nonresidential capital depreciation	10%	10%
δ_h	0.00625	Annual housing depreciation	2.5%	2.5%
Financial sector				
ϕ	4.15e−5	Mortgage interest rate spread	2.65%	2.65%
ζ	0.02	Mortgage origination fee	2%	2%
Legal environment				
γ_f	0.95	Average years duration of foreclosure flag	5	5
		Parameters determined jointly		
Preferences				
β	0.96397	Nonresidential capital to GDP	1.64	1.62
ω	1.48e−7	Homeowner housing wealth to earnings	3.62	3.62
σ	4.70	Borrower mortgage debt to earnings	2.03	2.05
Production technologies				
A_c	0.21609	Mean quarterly labor earnings	0.25	0.25
A_h	54.757	Housing services to GDP	15%	15%
Housing markets				
$\underline{h}$	2.92	Home ownership rate	64%	64.7%
γ_b	2.55	Buyer search duration in weeks	10	9.96
A_b	1.0065	Minimum buying premium	0.5%	0.5%
κ_b	0.005	Maximum buying premium	2.5%	2.5%
ξ	0.013	Seller search duration in weeks	17	16.96
A_s	2.2917	Average realtor fees	6%	6%
κ_s	0.1375	Maximum selling discount (incl. realtor fees)	20%	20%
γ_s	0.69	Annual foreclosure rate	1.4%	1.37%
Foreclosure sales				
χ	0.1199	Foreclosure selling price discount	22%	21.95%
λ	0.4051	REO time on the market in weeks	52	52.05

For buyers, I target a minimum buying premium $\underline{x}_b(p_h)/p_h h$ of 0.5% and a maximum buying premium $\overline{x}_b(p_h)/p_h h$ of 2.5%, consistent with Gruber and Martin (2003). For sellers, I target a minimum selling discount where sellers are guaranteed to immediately sell, $(p_h h - \overline{x}_s(p_h))/p_h h$, of 6% to match direct realtor expenses in the data. I target a maximum selling discount $(p_h h - \underline{x}_s(p_h))/p_h h$ of 20%, consistent with findings in Garriga and Schlagenhauf (2009) and evidence from pre-foreclosure sales price discounts.[18]

4. Results

I begin this section by describing the baseline model results. Next, I assess the dynamic effects of search frictions and their interaction with the mortgage market. Last, I analyze the impact on housing dynamics of a foreclosure law reform that makes all mortgages full recourse. I summarize the main takeaways as follows:

1. House prices and sales are strongly procyclical and volatile; time on the market and foreclosures are strongly countercyclical and volatile.

2. The interaction of search frictions and endogenous mortgage credit generates liquidity spirals that magnify house price swings due to the spillover of house selling risk to foreclosure risk.

3. The combination of search frictions, endogenous credit, and equilibrium default generates house price movements that exhibit short-run momentum as well as asymmetric boom–bust dynamics.

4. Enacting stringent foreclosure recourse laws dampens house price dynamics and substantially reduces foreclosures.

4.1 *Baseline results*

To evaluate the performance of the baseline economy, I compare the dynamics of Hodrick–Prescott (HP)-filtered time series generated by the model to the equivalent HP-filtered series in the U.S. data from 1975 to 2010.[19]

4.1.1 *Housing and foreclosure dynamics* Table 2 reports the co-movement of existing homeowner sales with house prices, the foreclosure rate, and months supply, which proxies for average selling time on the market.[20] In the data, sales exhibit significant positive co-movement with house prices and negative co-movement with months supply and the foreclosure rate. The baseline model successfully matches these co-movements, both qualitatively and quantitatively. Furthermore, both the model and the data feature procyclical prices and existing sales alongside countercyclical months supply and foreclosures, as shown in Table 3.

To understand these dynamics, recall that productivity shocks are the source of fluctuations in the model. A positive shock to aggregate productivity increases incomes,

[18] RealtyTrac reports pre-foreclosure discounts ranging from 1.28% to 34.94%. Unlike REOs, which sell at a discount largely because of degradation caused by extended vacancy, pre-foreclosure houses are likely to sell at a discount because of financial urgency to sell.

[19] I omit 2011–2014 because of the recent spate of legal and industry practice changes in the housing and mortgage markets. Due to the protracted nature of housing booms and busts, I use a smoothing parameter of 10^8 to avoid excessively removing variation.

[20] I ignore new sales because construction firms sell new housing in nondiscrete units of "putty–clay" to real estate firms. However, I *do* analyze the value of new housing, that is, residential investment.

TABLE 2. Housing co-movements.

	Data	Model
Corr(sales, prices)	0.50	0.59
Corr(sales, months supply)	−0.68	−0.74
Corr(sales, foreclosure rate)	−0.65	−0.48

Note: Model sales consists of all sales by existing owners. Sales data are the existing sales series reported by the National Association of Realtors.

TABLE 3. Housing dynamics.

	$\sigma_x/\sigma_{\text{output}}$		$\rho_{x,\text{output}}$	
x	Data	Model	Data	Model
House prices	2.07	1.90	0.50	0.95
Existing sales	3.93	4.35	0.73	0.13
Months supply	6.11	6.46	−0.44	−0.88
Foreclosure rate	4.96	16.32	−0.64	−0.88

Note: Relative standard deviations and correlations with gross domestic product (GDP) of HP-filtered time series. See Table 11 in the Appendix for definitions and sources.

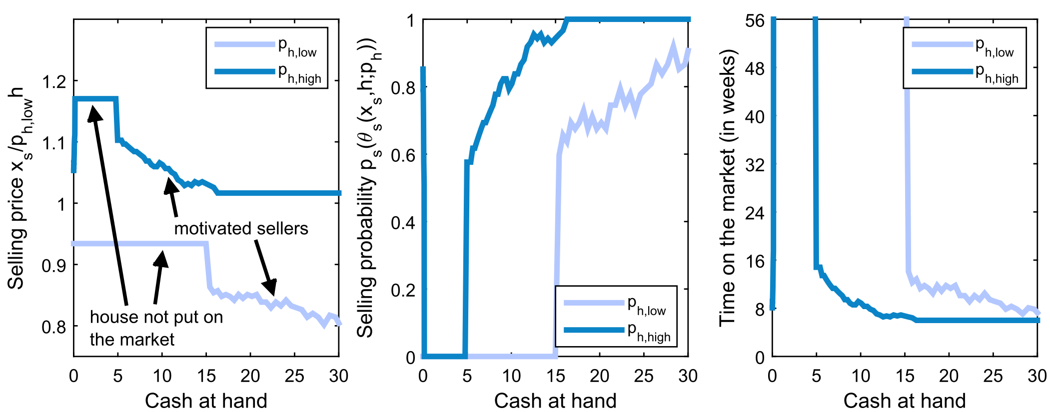

FIGURE 1. Selling price, selling probability, and time on the market (TOM) as a function of cash at hand for homeowners wishing to upgrade.

which leads to higher demand for housing and a textbook response of higher prices and sales. However, standard competitive models of housing cannot account for the decrease in months supply. Under perfect competition, homeowners can only respond to changing market conditions by deciding whether or not to sell their house at the market price. However, in a decentralized housing market with search frictions, homeowners have some price-setting power.

Figure 1 plots homeowners' choice of selling price as a function of cash at hand. As the first panel of the figure shows, homeowners with low cash at hand do not wish to move and therefore do not put their house on the market. However, as cash at hand increases, homeowners gradually lower their selling price to sell more quickly.

When the shadow housing price p_h increases, more real estate agents enter the market to match with sellers, driving up market tightnesses $\theta_s(x_s, h)$ and seller trading probabilities $p_s(\theta_s(x_s, h))$ at every listing price x_s. In response to the improvement in trade probabilities, homeowners sell more quickly *and* at a higher price because they increase x_s by less than the change in p_h. Therefore, unlike in competitive models of housing, selling behavior with search frictions adjusts along both the price and selling time margins.

The countercyclicality of foreclosures can be attributed to three effects. First, homeowners can better afford mortgage payments when they have higher incomes during economic expansions. Second, the increase in selling probabilities from higher p_h makes it easier for distressed homeowners to sell their houses. Last, both higher incomes and higher trading probabilities loosen credit constraints, which makes refinancing easier. I delve into these effects in my discussion of the effects of search frictions.

Also consistent with the data, the model generates significant volatility in prices, sales, months supply, and foreclosures. The model's almost exact matching of price, sales, and months supply volatilities represents a particular success, given the difficulty the literature has had in generating sufficient volatility for even a subset of these variables. Search frictions and fluctuations in endogenous credit constraints (determined by mortgage prices q_m^0) play an important role in amplifying housing dynamics—channels that I explore momentarily.

Though the model generates significantly higher foreclosure volatility than in the data, much of the apparent difference arises because of higher frequency fluctuations in the model, rather than larger absolute swings. During model simulations, the foreclosure rate fluctuates between 0.2% and 1.75%, which is in line with empirical foreclosure rate fluctuations before the Great Recession. Furthermore, if I expand the foreclosure rate to include all mortgages 90+ days late, the empirical relative volatility nearly doubles to 8.92.[21]

4.1.2 *Consumption, investment, and portfolio dynamics* Turning to standard business cycle variables, Table 4 shows that the model generates consumption and investment dynamics that mimic those in the data. The model and empirical volatilities of aggregate consumption and investment correspond almost exactly, and the model matches the relative volatilities of each component of investment reasonably well. In particular, the model generates 83% of the empirical volatility in residential investment.

Volatile house prices largely drive these swings in residential investment—first, by causing fluctuations in the value of new housing and, second, by generating strong responses in construction, even with the constraining impact of fixed new land/permits. In fact, a moderate amount of inelasticity in construction actually contributes to higher residential investment volatility by magnifying house price movements.

[21] The foreclosure rate is also likely to be less volatile in the data because banks do not generally *immediately* foreclose on borrowers in the early stages of a housing bust, while they do in the model.

Table 4. Consumption, investment, and portfolio dynamics.

	$\sigma_x/\sigma_{\text{output}}$		$\rho_{x,\text{output}}$	
x	Data	Model	Data	Model
Consumption	0.65	0.55	0.92	0.93
Composite	0.72	0.62	0.91	0.94
Housing	0.60	0.33	0.55	0.75
Investment	2.97	2.99	0.94	0.96
Nonresidential	2.69	2.93	0.78	0.92
Residential	5.15	4.29	0.92	0.90
Financial assets	1.76	1.61	0.65	0.91
Mortgage debt	1.64	2.67	0.22	0.85

Note: Relative standard deviations and correlations with GDP of HP-filtered time series. See Table 10 in the Appendix for definitions and sources.

Reflecting the importance of wealth and debt heterogeneity, both the model and the data demonstrate interesting cyclical behavior of household portfolios. Financial assets, housing wealth, and mortgage debt are *all* procyclical and more volatile than GDP. As Table 4 demonstrates, the model almost exactly matches the relative volatility of assets. The model also generates procyclical, volatile mortgage debt—to excess, in fact—though the model performs well compared to the recent literature. For example, Iacoviello and Pavan (2013) generate almost four times the mortgage volatility as in the data.

The fact that households increase assets *and* debt during economic upturns implies that households do not single-mindedly use their improved financial position to deleverage. Instead, households take on increased mortgage debt to purchase more housing and simultaneously insure themselves against the future risk of an economic downturn. By borrowing more during periods with loose credit constraints, households use the funds to purchase assets for precautionary saving, rather than being forced to borrow to smooth consumption during downturns when credit constraints are tight. Figure 6 in the Appendix graphically summarizes the economic response to a small, persistent increase in z_c.

4.1.3 *The role of land and construction* Although this paper focuses on other novel mechanisms, Chu (2013) and Kahn (2009) point out the importance of land as a fixed factor in generating housing market volatility. In the current calibration, the share of land is 33%, in line with national data. However, Table 5 shows the impact of two alternative values of the land share. First, I consider a higher land share of 0.8 as in San Francisco. Second, I look at a land share of 0.15 as in Houston. Note that I do *not* change any other aspect of the calibration to match the economies in San Francisco or Houston. As such, Table 5 should be interpreted as a comparative dynamics exercise rather than an analysis of regional housing dynamics.

Strikingly, a large increase in the land share from 0.33 to 0.8 only magnifies house price swings by 15%, while a decrease in the land share to 0.15 dampens house price dynamics by almost 30%. This same asymmetry shows up in the impact of land on sales,

Table 5. Dynamics with different land shares.

	$\sigma_x/\sigma_{\text{output}}$		
x	Baseline	$\alpha_L = 0.8$	$\alpha_L = 0.15$
House prices	1.90	2.20	1.38
Existing sales	4.35	6.02	2.11
Months supply	6.46	6.96	4.72
Foreclosure rate	16.32	25.59	9.37
Residential investment	4.29	2.57	5.02

Note: Relative standard deviations and correlations with GDP of HP-filtered time series. See Table 11 in the Appendix for definitions and sources.

Table 6. Dynamics without search frictions.

	$\sigma_x/\sigma_{\text{output}}$		
x	Data	Baseline	No Search
Investment	2.97	2.99	3.09
Nonresidential	2.69	2.93	3.24
Residential	5.15	4.29	3.38
House prices	2.07	1.90	1.58
Existing sales	3.93	4.35	8.15
Months supply	6.15	6.46	–
Foreclosure rate	4.96	16.32	–

months supply, and the foreclosure rate. The reverse pattern shows up in residential investment, however. The direct dampening effect of a higher land share on construction volatility is counteracted by the effect of endogenously higher house price volatility. This indirect price effect is small when moving from $\alpha_L = 0.33$ to $\alpha_L = 0.8$ but shows up strongly at $\alpha_L = 0.15$. Overall, the volatility of residential investment exhibits an inverse U-shape in the land share.

4.2 *Search frictions and housing dynamics*

Search frictions greatly influence housing and foreclosure dynamics. To determine the effects of search, I compare the baseline economy to the limit economy with frictionless, competitive housing. Contrasting the dynamics of these two economies, three differences stand out. First, months supply does not fluctuate in the no-search economy because houses always sell instantly, and foreclosures almost disappear.[22] Second, the co-movement between sales and prices decreases from 0.59 to 0.27. Third, the volatilities of residential investment and house prices decline substantially while existing sales volatility nearly *doubles*, as shown in Table 6. Below, I explain the mechanisms behind these results as well as how search frictions help resolve other housing puzzles.

[22]The foreclosure rate fluctuates between 0% and 0.14% in the no-search economy.

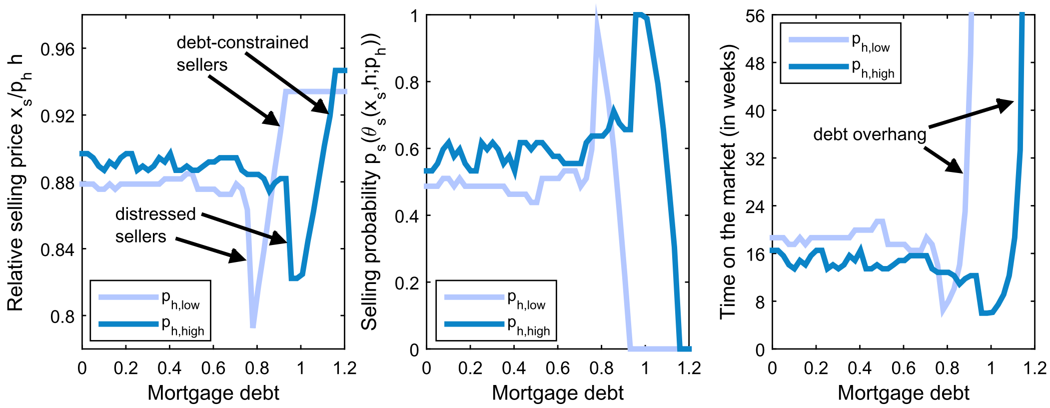

FIGURE 2. Selling discount, selling probability, and TOM as a function of mortgage debt (normalized by $p_{h,\text{low}}h$) for homeowners wishing to downsize or rent.

4.2.1 *Liquidity spirals and amplification* One of the major successes of the model is its ability to generate sufficient volatility in house prices and residential investment. Though other factors also contribute to these large swings, search frictions generate an additional 20% volatility in prices and 27% volatility in residential investment. This amplification primarily occurs because of liquidity spirals akin to those in Brunnermeier and Pedersen (2009) that arise from the interaction of search-based housing illiquidity with endogenous mortgage credit constraints.

To explain the nature of liquidity spirals, I appeal to the discussion in Hedlund (2015) that establishes a link between search risk and foreclosure risk. Figure 2 shows the optimal *relative* selling price $x_s/p_h h$, selling probability, and expected time on the market as a function of mortgage debt for sellers wishing to downsize or rent. Selling price is almost invariant to mortgage debt for low values of leverage but exhibits strong nonmonotonicity as leverage approaches and exceeds an 80% loan-to-value ratio. When leverage hits moderately high levels, low asset homeowners trying to avoid financial insolvency become “distressed sellers” who sharply reduce their selling price to quickly unload their house. These sellers have sufficient home equity to absorb large losses but are unable to extract equity through refinancing because intermediaries view them as risky borrowers. With even higher leverage, homeowners have insufficient equity to sharply lower their selling price. Instead, debt overhang forces these sellers to set high prices, which causes their houses to sit longer on the market.[23] Eventually, some sellers default and enter foreclosure, and an influx of REO houses for sale occurs that depresses the housing market.

Banks anticipate this behavior and price higher default premia into new mortgages during times of lower prices and worse housing liquidity, thus exacerbating the debt overhang problem. These higher default premia tighten access to credit, which simultaneously makes refinancing more difficult and prevents new buyers from entering the

[23] Genesove and Mayer (2001) confirm this selling behavior empirically.

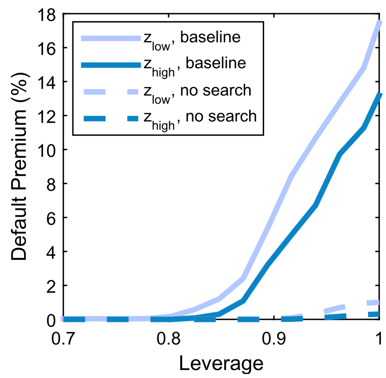

Figure 3. Example mortgage default premia.

housing market to prop up prices and liquidity. In short, search magnifies booms because higher prices increase selling probabilities, which reduces foreclosures, lowers default premia, and loosens credit constraints, resulting in even higher prices.

During simulations of the baseline economy, *average* default premia for newly originated mortgages with 80%+ leverage fluctuate between 0.3% and 2%, while average default premia fluctuate between 0.5% and 3.5% for 90%+ leverage mortgages and between 0% and 6% for 95%+ leverage mortgages.[24] By contrast, less default risk and fewer high leverage borrowers in the no-search economy generate only trivial default premia, as in Figure 3.

4.2.2 *Momentum and asymmetry in housing dynamics* Besides amplifying movements in house prices and residential investment, search frictions help resolve two important house price puzzles. First, house prices exhibit short-run momentum, as documented in Case and Shiller (1989), Capozza, Hendershott, and Mack (2004), Head, Lloyd-Ellis, and Sun (2014), and several other papers. Second, house price busts tend to be slower and shallower than booms—with some notable exceptions—which suggests a degree of downward price stickiness.[25] The baseline model generates dynamics consistent with both of these phenomena, as shown in Figure 4. Specifically, the model generates prolonged booms followed at times by mild slumps, as in the second panel, or else by sharp crashes and prolonged slumps, as in the last panel. These dynamics mimic the shallow U.S. housing bust in the early 1990s and the recent sharp, prolonged housing bust, respectively.

Search frictions help generate house price momentum in two ways. First, search frictions spread out the impact of economic shocks. Trading delays simultaneously reduce existing sales volatility from 8.15 to 4.35 and increase the co-movement of sales and prices from 0.27 to 0.59. Furthermore, these trading delays cause current house prices to improve current *and* future liquidity, which raises the resale value of housing and

[24] In fact, these fluctuations actually understate the cyclicality of credit constraints because homeowners are unlikely to take out mortgages with exceptionally high default premia.

[25] See, for example, Case and Quigley (2008) and Genesove and Mayer (2001).

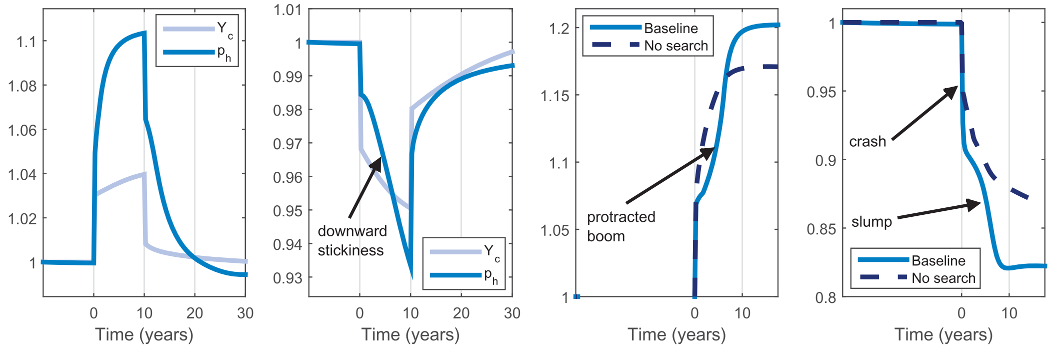

Figure 4. Left two panels: House price responses to small, 10-year z_c shocks. Right two panels: House price booms and busts in the baseline and no-search economies.

pushes up future prices. Second, liquidity spirals generate persistent price changes from the positive feedback loop of higher prices, less debt overhang, and looser credit.

Search frictions also help explain the asymmetry of booms and busts. During a boom, the virtuous cycle of higher prices, higher liquidity, and expanding credit combines with partially inelastic construction to generate large, persistent price increases. However, depending on the severity of the bust, most homeowners lack a strong incentive to sell their houses during times of decreasing prices. The combination of expected mean reversion, debt overhang, and long-term mortgages taken out during more favorable conditions causes most homeowners to resist substantially lowering their selling price. Sharp price declines—spurred partly by a spike in distressed and foreclosure sales—usually only occur after protracted booms followed by large productivity drops.

4.3 *Discussion*

The main quantitative success of the model is its ability to match the volatilities and co-movements of the main housing and business cycle variables. Delivering sufficient volatility of house prices represents a particular victory given the difficulty the literature has had in this endeavor. However, equally notable is the model's ability to match the co-movement of prices, sales, and, especially, time on the market (months supply).

Several mechanisms account for these dynamics. Abstracting from search and mortgage default, the response of the economy to productivity shocks follows a perhaps familiar chain of reasoning. Household incomes rise in response to an increase in z_c, which generates higher consumption and an increase in housing demand. Higher housing demand coupled with relatively inelastic supply generates an increase in house prices. The reverse happens in a downturn.

The addition of search frictions and endogenous mortgage credit with equilibrium mortgage default adds several quantitatively important layers to this basic story. First, search frictions in isolation propagate the effect of shocks over time, as in Head, Lloyd-Ellis, and Sun (2014) and Díaz and Jerez (2013). However, only Head, Lloyd-Ellis, and Sun (2014) generates short-run momentum in house *prices*—as this paper does.

Second, search frictions interact with endogenous mortgage prices in a qualitatively and quantitatively important way. In a downturn, decreased household income causes a drop in housing demand, which drives down market tightnesses, that is, housing liquidity. Ceteris paribus, the drop in housing liquidity causes homeowners to sell at lower prices *and* experience longer time on the market. The presence of mortgage debt exacerbates the lengthened time on the market by introducing a form of price stickiness—homeowners cannot list their price so low as to be unable to pay off their mortgage upon selling.[26] This magnified time on the market causes some financially distressed homeowners to default on their mortgages, which adversely affects the housing market in two ways. First, the unloading of foreclosure properties onto the market depresses market tightnesses further. Second, the economy-wide increase in foreclosure risk resulting from reduced housing liquidity causes financial intermediaries to reduce mortgage prices, that is, funding liquidity (which is equivalent to causing a contraction in endogenous credit constraints). These liquidity spirals act as a novel housing market parallel to those in Brunnermeier and Pedersen (2009) that are absent in any of the existing housing literature. In fact, in Head, Lloyd-Ellis, and Sun (2014), search frictions actually *dampen* the volatility of house prices.

Last, the combination of search and mortgage debt helps explain the asymmetry of housing dynamics. Long-term mortgages reduce the incentive of homeowners to sell in temporary downturns, while the option to foreclose can lead to sharp initial drops in house prices during severe downturns. By contrast, the virtuous cycle of higher housing liquidity, expanded credit, and long-term mortgages explains the large, persistent booms observed in housing markets. Considering only search or credit constraints in isolation misses some of these key mechanisms.

4.4 *Reforming foreclosure laws*

Currently, only 12 nonrecourse states forbid financial institutions from suing borrowers when a foreclosure sale does not recover the entire mortgage balance. The other 38 recourse states permit such deficiency judgments, thus subjecting foreclosed borrowers to the additional penalty of having their other assets seized. However, conventional wisdom suggests that such deficiency judgments rarely occur due to high legal costs and low returns to pursuing borrowers after foreclosure.[27] Theory and empirical evidence that I discuss later suggests that such a de facto nonrecourse environment encourages speculative behavior. In this section, I analyze the impact on housing dynamics of a foreclosure reform that makes *all* mortgages full recourse with a *costless* process for initiating deficiency judgments. The model in this paper proves uniquely suitable for such

[26] The Q4 2008 Office of the Comptroller of the Currency (OCC) and Office of Thrift Supervision (OTS) Mortgage Metrics Report states that there were only 5.4% as many short sales as foreclosures in early 2008. Prior to the Great Recession, short sales were even less common. In addition, as discussed by Hedlund (2015), the implied positive relationship in the model between mortgage debt and list price at high leverage ranges is consistent with empirical evidence in Genesove and Mayer (1997, 2001).

[27] See Corbae and Quintin (2015), Campbell (2013), Campbell and Cocco (2015), Jones (1993), and Bhutta, Dokko, and Shan (2010) for further discussion.

an analysis because of its quantitative success in matching endogenous house price dynamics and because of the rich house buying, selling, and portfolio choice behavior that it reflects, consistent with the data.

4.4.1 *Mortgage prices and value functions with recourse* In the baseline model with nonrecourse mortgages, the recovery ratio to a bank of foreclosing on a house, conditional on realizations (e', s') and $\mathbf{Z}'$, enters (12) as

$$\min\left\{1, \frac{J_{\text{REO}}(h; \mathbf{Z}')}{m'}\right\}.$$

Under this legal regime, the numerator of the recovery ratio consists only of the value of repossession, which does not depend on (e', s'). Under the mortgage reform, the recovery ratio increases to

$$\min\left\{1, \frac{J_{\text{REO}}(h; \mathbf{Z}') + \eta y'}{m'}\right\},$$

where $y' = w(\mathbf{Z}')e's' + b'$ is cash at hand next period based on the borrower's bond holdings and labor realizations. I set $\eta = 0.9$ to allow lenders to seize up to 90% of a household's financial assets. Ceteris paribus, the higher recovery ratio lowers default premia and expands the supply of mortgage credit. Increased borrower reluctance to default because of the reform magnifies this credit expansion.

Besides the recovery ratio, the value function associated with mortgage default also changes, from (20) to

$$\begin{aligned} &W_{\text{own}}(y, m, h, s, 0; \mathbf{Z}) \\ &\quad = \max\bigl\{(V_{\text{rent}} + R_{\text{buy}})\bigl(y + \max\bigl\{-\eta y, J_{\text{REO}}(h; \mathbf{Z}) - m\bigr\}, s, 1; \mathbf{Z}\bigr), \\ &\qquad V_{\text{own}}(y, m, h, s, 0; \mathbf{Z})\bigr\}. \end{aligned}$$

In the event of foreclosure, household cash at hand increases by $J_{\text{REO}}(h; \mathbf{Z}) - m$ if the intermediary values the house at more than the outstanding debt (a highly unlikely scenario given the various repossession costs and the fact that homeowners with that much equity should be able to successfully sell to avoid default). More likely is $J_{\text{REO}} < m$, in which case cash at hand decreases by the amount of negative equity up to a maximum of ηy.

4.4.2 *Dynamic effects of the reform* Table 7 demonstrates the effects of the considered foreclosure reform on housing dynamics. The economy with costless, full recourse exhibits 12% less house price volatility, 17% less residential investment volatility, and 38% *higher* existing sales volatility than the baseline economy. Furthermore, fluctuations in months supply drop by over 85%, while foreclosures almost disappear.

The foreclosure reform reduces price, selling time, and foreclosure volatility primarily by reducing speculative borrowing. Increased borrower reluctance to default and higher recovery ratios drive down default premia, which increases the supply of credit.

Table 7. Dynamics with recourse mortgages.

	$\sigma_x/\sigma_{\text{output}}$		
x	Data	Baseline	Recourse
Investment	2.97	2.99	2.93
Nonresidential	2.69	2.93	3.01
Residential	5.15	4.29	3.57
Mortgage debt	1.64	2.67	2.98
House prices	2.07	1.90	1.68
Existing sales	3.93	4.35	5.99
Months supply	6.15	6.46	0.93
Foreclosure rate	4.96	16.32	–

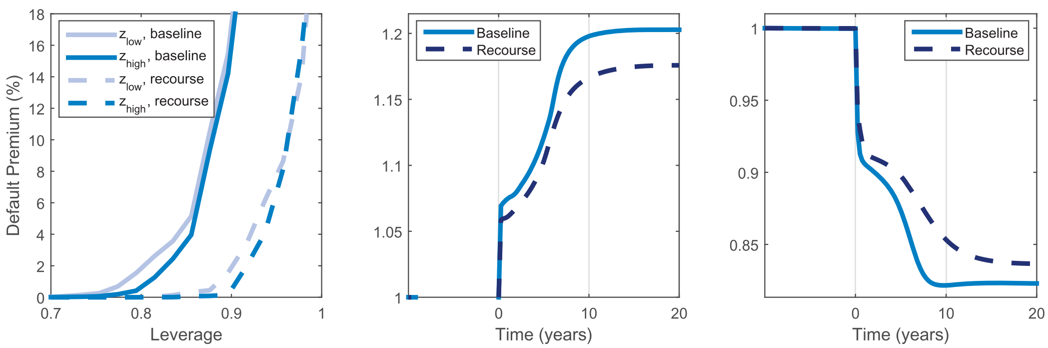

Figure 5. (Left) Example default premia. (Right two) Comparison of boom and bust transitions caused by a permanent z_c shock.

However, homeowners largely avoid taking out risky, high leverage mortgages. Simulated average default premia hover around 0%, even for those few borrowers who take out high leverage mortgages.

This reduction in risky borrowing, combined with the expansion of credit, prevents debt overhang and the emergence of liquidity spirals. Homeowners with moderately high leverage no longer become "distressed sellers" because they can extract equity at low cost through refinancing. Furthermore, the lack of foreclosure activity and REO houses flooding the market during housing busts mediates price declines. Augmented by fewer distressed and debt-constrained sellers, the disappearance of countercyclical REO sales also explains the increased volatility and procyclicality of existing sales as well as the drastic drop in months' supply volatility. The recourse model does, however, still generate protracted booms and busts, which confirms the importance of search frictions even without the amplification of liquidity spirals. Figure 5 shows the expansion of credit (reduction in default premia) due to the reform as well as the dampened dynamics of house prices in a boom and a bust.

4.4.3 *Empirical support* Although deficiency judgments rarely occurred prior to the Great Recession, recent papers have found differences in housing market behavior between recourse and nonrecourse states in recent years. Dobbie and Goldsmith-Pinkham (2015) use state variation in recourse mortgage laws and bankruptcy homestead exemptions to estimate the effect of debtor protections on regional economies. They find that underwater homeowners with nonrecourse protection were 15.5 percentage points more likely to default on their mortgage and 9.4 percentage points more likely to experience foreclosure. With regard to the regional economy, a 10 percentage point increase in the fraction of individuals with nonrecourse protection decreased house prices by 4.7 percentage points at the zip code level. In addition, areas with nonrecourse protection saw drops in consumption and employment while areas with stronger bankruptcy protections actually saw increases, suggesting that the magnified drop in house prices due to nonrecourse statutes depressed the local economy. Last, Dobbie and Goldsmith-Pinkham (2015) conjecture that debtor protections contributed to the run up in debt prior to the Great Recession. My model provides support for this conjecture, as the higher demand for borrowing in the nonrecourse baseline model dominates the reduced supply of mortgage credit.

In separate work, Bao and Ding (forthcoming) find evidence that nonrecourse states saw faster price growth from 2000 to 2006 and experienced a sharper drop in house prices from 2006 to 2009, but then rebounded more rapidly between 2009 and 2013. In a similar vein, Mian, Sufi, and Trebbi (2015) find that states without a judicial requirement—that is, states that allow lenders to foreclose on delinquent borrowers without going through the court system—were more than twice as likely to foreclose on delinquent borrowers. Furthermore, such states experienced larger price declines from 2007 to 2009 and a stronger recovery from 2011 to 2013. In short, the increased presence of foreclosure fire sales generates additional volatility in housing markets, as further supported by findings in Anenberg and Kung (2014). I find that this same mechanism generates additional housing volatility in the baseline nonrecourse economy compared to the economy with recourse.

4.4.4 *Policy discussion and welfare* In light of the recent global housing boom and bust, several papers have shed some perspective on key differences between the housing and mortgages markets in the United States and other countries. Focusing on the United States and Europe, Campbell (2013) and Jaffee (2015) document that European countries—with a few exceptions—tend to observe less volatility in house price movements than does the United States. Furthermore, during the recent housing bust, even countries that experienced large drops in house prices, such as Denmark, have largely avoided the mortgage default crisis that has ravaged the United States. They point out that these European countries tend to actually have *less* government intervention in the housing market and in many cases also have *higher* home ownership rates than in the United States.

Campbell (2013) and Jaffee (2015) identify two key distinctions between United States and European mortgage markets that may account for the superior European performance. First, mortgages in Europe are almost universally full recourse mortgages, and lenders have an easy time obtaining deficiency judgments. In general, the borrower's responsibility even survives past bankruptcy. The second key difference arises from the funding of mortgages. In the United States, a transition away from traditional deposit-based funding has led to the transcendence of securitization. By contrast, lenders in most European countries use covered bonds—that is, ownership claims to originators—to finance mortgages. In this system, mortgages remain on the books of originators, which alleviates several incentive problems.[28]

To go beyond the macroeconomic effects of the recourse experiment in this paper's model, I turn to the evaluation of welfare. As the measure of welfare, I compute the population average consumption-equivalent welfare change of moving from the nonrecourse environment to the recourse environment. Mathematically,

$$\Delta W(\mathbf{Z}) = \int 100\left(\left[\frac{W^{\text{recourse}}(y, m, h, s, f; \mathbf{Z})}{W(y, m, h, s, f; \mathbf{Z})}\right]^{1/(1-\sigma)} - 1\right) d\Phi,$$

where $W(y, m, h, s, f; \mathbf{Z}) = W_{\text{own}}(y, m, h, s, f; \mathbf{Z})$ for homeowners and $W(y, m, h, s, f; \mathbf{Z}) = (V_{\text{rent}} + R_{\text{buy}})(y, s, f; \mathbf{Z})$ for renters.

Note that the average welfare change $\Delta W(\mathbf{Z})$ depends on the aggregate state of the economy, that is, at which point in the business cycle the policy gets implemented. To establish some points of comparison, I also compute the average welfare change in the steady state as well as within certain subsets of households. Table 8 reports that the recourse policy lowers welfare by 0.88% in consumption units in the steady state. Although credit supply expands because of higher recovery ratios and a reduced propensity of borrowers to default, the policy change reduces the consumption insurance afforded by nonrecourse foreclosure. This loss of insurance dominates in terms of welfare. Furthermore, as one might expect, the welfare losses are concentrated among the subset of households with high leverage.

Moving to the dynamic economy, the average welfare change fluctuates between -0.03% and -0.17% with a mean of -0.09%. In other words, the reform is essentially welfare neutral. This sizable attenuation of the welfare loss comes about from the fact that recourse stabilizes the dynamics of the housing market. The average welfare gain

Table 8. Welfare effects of recourse policy.

	Steady State	Dynamic Economy	Gain From Stabilization
ΔWelfare, all	−0.88%	−0.09%	0.79%
ΔWelfare, renters	−0.35%	0.08%	0.43%
ΔWelfare, LTV ≥ 80%	−2.20%	−0.05%	2.15%
ΔWelfare, LTV ≥ 90%	−2.50%	−1.00%	1.50%
ΔWelfare, LTV ≥ 95%	−2.63%	−1.68%	0.95%

Note: Average consumption-equivalent welfare change from implementing the recourse mortgage reform. Figures for the dynamic economy are simulated averages. LTV denotes the loan-to-value ratio.

[28] The Danish system has received particular acclaim and is one of the few European countries with a prevalence of fixed-rate mortgages. In addition to having recourse and covered bond financing, Danish mortgages are assumable (i.e., can be transferred to subsequent owners) and are put into nationally diversified pools.

from this stabilization comes to 0.79%. Renters come out slightly ahead due to the reform, while heavily indebted homeowners still experience welfare losses. However, the magnitude of the losses drops significantly.

Last, the correlation between house prices and $\Delta W(\mathbf{Z})$ is 0.57 for the overall population and −0.65 for renters. Renters prefer the implementation of the policy to occur at the trough of a housing bust because they expect prices to rise and would benefit from a greater supply of credit. Homeowners, on the other hand, suffer a smaller welfare loss if the policy gets enacted during a boom, when the insurance value of default is already smaller.

As a caveat, the model omits several ingredients that could bias the welfare effects of this policy reform. First, the model abstracts from life cycle considerations. Young households that experience binding credit constraints may benefit more from the increase in credit that accompanies the reform. On the other hand, these same households may place greater value on the default option. In addition, the model does not feature any goods or labor market frictions that could generate larger spillovers from housing to the rest of the economy. Taking such channels into account may increase the stabilization benefits of the reform.

5. Conclusions

Search frictions in the housing market interact with endogenous credit constraints to produce quantitatively accurate housing, mortgage debt, and foreclosure dynamics. The liquidity spirals and gradual boom–bust dynamics generated by the model accord strongly with the data, making the model a good launching point for future theoretical and policy-related research. Furthermore, the tractable formulation of directed search in the housing market with rich, two-sided heterogeneity and aggregate uncertainty allows the model to address issues that affect housing simultaneously through financial and nonfinancial channels. For example, future work could look at the role of state variation in credit conditions, housing supply factors, and government policy in explaining different regional house price dynamics. Alternatively, the model provides a useful framework in which to analyze optimal monetary and fiscal policy with frictional housing.

Appendix

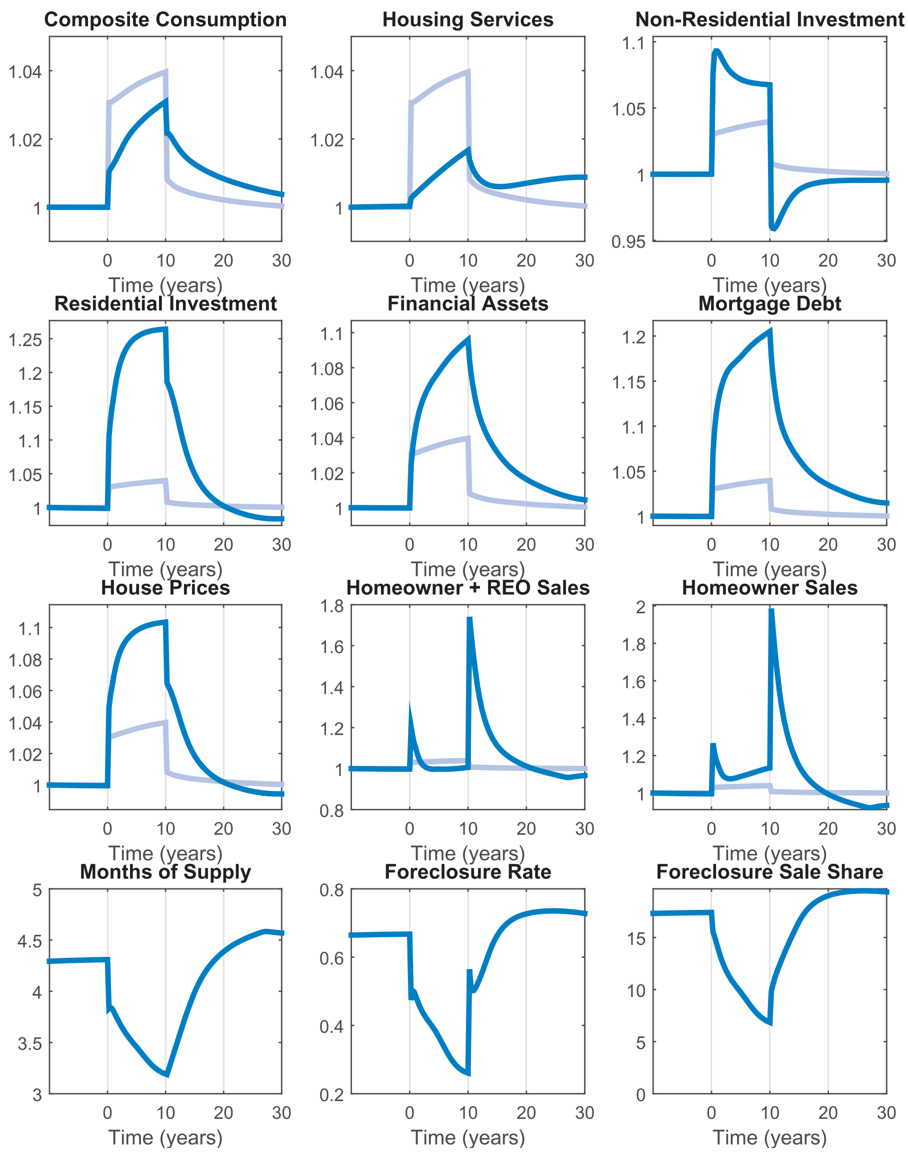

Figure 6. Economic response to a small, 10-year *increase* in z_c. With the exception of months supply, the foreclosure rate, and the foreclosure sales share, each series is initially normalized to 1 and is plotted alongside the output of the consumption good (the light curve) for reference.

Definition 1. A recursive equilibrium consists of

- household value and policy functions;
- production firm functions $K_c(\mathbf{Z})$, $N_c(\mathbf{Z})$, $L(\mathbf{Z})$, $S_h(\mathbf{Z})$, and $N_h(\mathbf{Z})$;
- intermediary functions $J_{\text{REO}}(h;\mathbf{Z})$, $R_{\text{REO}}(h;\mathbf{Z})$, $x_s^{\text{REO}}(h;\mathbf{Z})$, and $K(\mathbf{Z})$;
- prices r_h, $q_b(\mathbf{Z})$, $i(\mathbf{Z})$, $r_m(\mathbf{Z})$, $r(\mathbf{Z})$, $w(\mathbf{Z})$, $p_l(\mathbf{Z})$, $p_h(\mathbf{Z})$, and $q_m^0(m', b', h, s; \mathbf{Z})$;
- market tightnesses $\theta_b(x_b, h;\, p_h(\mathbf{Z}))$ and $\theta_s(x_s, h;\, p_h(\mathbf{Z}))$;
- an aggregate law of motion $\mathbf{Z}' = G(\mathbf{Z}, z_c')$;

such that the following statements hold:

1. *Household Optimality*: The value/policy functions solve (15)–(22).
2. *Firm Optimality*: Conditions (1)–(6) are satisfied.
3. *Intermediary Optimality*: Conditions (10)–(13) are satisfied.
4. *Market Tightnesses*: The variables θ_s and θ_b satisfy (8) and (9).
5. *Shadow Housing Price*: We have $D_h(p_h(\mathbf{Z});\mathbf{Z}) = S_h(p_h(\mathbf{Z});\mathbf{Z})$.
6. *Land/Permits*: We have $L(\mathbf{Z}) = \bar{L}$.
7. *Labor Market Clears*: We have $N_c(\mathbf{Z}) + N_h(\mathbf{Z}) = \sum_{s\in S} \int_E e \cdot sF(de)\Pi_s(s)$.
8. *Capital Market Clears*: We have $K_c(\mathbf{Z}) = K(\mathbf{Z})$.
9. *Bond Market Clears*: There is no active trading of international bonds.
10. *Resource Constraint*: Total use of the consumption good equals total production, $z_c F(K_c(\mathbf{Z}), N_c(\mathbf{Z}))$.
11. *Aggregate Law of Motion*: The law of motion $\mathbf{Z}' = G(\mathbf{Z}, z_c')$ is consistent with the Markov process induced by the exogenous processes π_s, π_z, and F, and all relevant policy functions.

Table 9. Standard business cycle statistics.

x	σ_x/σ_Y	ρ_{xY}	ρ_{xx}	x/Y
		Data		
Output (Y)	1.00	1.00	0.72	1.00
Consumption	0.65	0.92	0.80	0.81
Composite	0.72	0.91	0.79	0.66
Housing	0.60	0.55	0.81	0.15
Investment	2.97	0.94	0.63	0.20
Nonresidential	2.69	0.78	0.51	0.14
Residential	5.15	0.92	0.77	0.05
		Baseline		
Output (Y)	1.00	1.00	0.87	1.00
Consumption	0.55	0.93	0.94	0.79
Composite	0.62	0.94	0.94	0.64
Housing	0.33	0.75	0.97	0.15
Investment	2.99	0.96	0.81	0.21
Nonresidential	2.93	0.90	0.77	0.16
Residential	4.29	0.90	0.93	0.04
		No Search		
Output (Y)	1.00	1.00	0.86	1.00
Consumption	0.56	0.93	0.94	0.80
Composite	0.61	0.94	0.94	0.65
Housing	0.34	0.82	0.96	0.15
Investment	3.09	0.96	0.79	0.20
Nonresidential	3.24	0.91	0.75	0.15
Residential	3.38	0.91	0.95	0.04
		Recourse		
Output (Y)	1.00	1.00	0.86	1.00
Consumption	0.57	0.93	0.94	0.79
Composite	0.64	0.94	0.94	0.64
Housing	0.29	0.77	0.96	0.15
Investment	2.93	0.96	0.80	0.21
Nonresidential	3.01	0.91	0.76	0.17
Residential	3.57	0.89	0.93	0.04

Table 10. Lagged correlations—output, consumption, and investment.

		Cross-Correlation of Output With								
x	σ_x/σ_Y	$x(-4)$	$x(-3)$	$x(-2)$	$x(-1)$	x	$x(+1)$	$x(+2)$	$x(+3)$	$x(+4)$
					Data					
Output (Y)	1.00	0.66	0.78	0.89	0.97	1.00	0.97	0.90	0.82	0.73
Consumption	0.65	0.65	0.75	0.84	0.90	0.92	0.90	0.86	0.81	0.75
Composite	0.72	0.65	0.75	0.84	0.89	0.91	0.89	0.86	0.81	0.75
Housing	0.60	0.24	0.28	0.32	0.37	0.41	0.45	0.48	0.49	0.48
Investment	2.97	0.56	0.69	0.80	0.89	0.94	0.90	0.83	0.73	0.62
Nonresidential	2.69	0.33	0.45	0.58	0.69	0.77	0.76	0.70	0.60	0.49
Residential	5.15	0.74	0.82	0.89	0.91	0.90	0.84	0.77	0.70	0.63
					Baseline					
Output (Y)	1.00	0.87	0.90	0.93	0.97	1.00	0.97	0.93	0.90	0.87
Consumption	0.55	0.79	0.83	0.86	0.90	0.93	0.92	0.92	0.91	0.90
Composite	0.62	0.80	0.84	0.87	0.91	0.94	0.93	0.92	0.92	0.91
Housing	0.33	0.61	0.64	0.67	0.70	0.74	0.75	0.75	0.76	0.76
Investment	2.99	0.85	0.88	0.91	0.94	0.96	0.92	0.87	0.82	0.77
Nonresidential	2.93	0.80	0.83	0.85	0.88	0.90	0.84	0.78	0.72	0.66
Residential	4.29	0.77	0.81	0.84	0.87	0.90	0.90	0.89	0.89	0.88
					No Search					
Output (Y)	1.00	0.86	0.89	0.93	0.97	1.00	0.96	0.93	0.89	0.86
Consumption	0.56	0.79	0.82	0.85	0.89	0.93	0.92	0.91	0.91	0.90
Composite	0.61	0.79	0.83	0.86	0.90	0.94	0.93	0.92	0.91	0.90
Housing	0.34	0.69	0.72	0.76	0.79	0.82	0.83	0.83	0.83	0.82
Investment	3.09	0.83	0.86	0.90	0.93	0.96	0.91	0.85	0.80	0.75
Nonresidential	3.24	0.79	0.82	0.85	0.88	0.91	0.85	0.78	0.72	0.66
Residential	3.38	0.78	0.81	0.84	0.87	0.91	0.91	0.91	0.90	0.89
					Recourse					
Output (Y)	1.00	0.86	0.90	0.93	0.97	1.00	0.97	0.93	0.90	0.86
Consumption	0.57	0.79	0.82	0.86	0.89	0.93	0.92	0.92	0.91	0.90
Composite	0.64	0.79	0.83	0.86	0.90	0.94	0.93	0.92	0.91	0.90
Housing	0.29	0.63	0.66	0.70	0.73	0.77	0.78	0.78	0.79	0.79
Investment	2.93	0.84	0.87	0.90	0.93	0.96	0.91	0.85	0.80	0.75
Nonresidential	3.01	0.80	0.82	0.85	0.88	0.91	0.84	0.78	0.72	0.66
Residential	3.57	0.76	0.79	0.82	0.86	0.89	0.89	0.89	0.88	0.87

Note: Quarterly data come from National Institute of Pension Administrators (NIPA) Table 1.5.5 and are deflated using the personal consumption expenditures (PCE) index. Data and model output are detrended with $\lambda = 10^8$ using the HP filter.

Table 11. Lagged correlations: house prices, sales, months supply, and foreclosures.

		Cross-Correlation of Output With								
x	σ_x/σ_Y	$x(-4)$	$x(-1)$	$x(-2)$	$x(-3)$	x	$x(+1)$	$x(+2)$	$x(+3)$	$x(+4)$
						Data				
Output (Y)	1.00	0.66	0.78	0.89	0.96	1.00	0.97	0.90	0.82	0.73
House prices	2.07	0.14	0.25	0.35	0.43	0.50	0.56	0.60	0.63	0.66
Existing sales	3.93	0.73	0.78	0.81	0.80	0.73	0.66	0.60	0.56	0.52
Months supply	6.15	−0.63	−0.61	−0.57	−0.52	−0.44	−0.37	−0.31	−0.28	−0.24
Foreclosure rate	4.96	−0.65	−0.68	−0.68	−0.67	−0.64	−0.60	−0.53	−0.47	−0.40
						Baseline				
Output (Y)	1.00	0.87	0.90	0.93	0.97	1.00	0.97	0.93	0.90	0.87
House prices	1.90	0.82	0.85	0.88	0.92	0.95	0.94	0.92	0.91	0.89
Existing sales	4.35	0.10	0.11	0.12	0.12	0.13	0.14	0.15	0.15	0.16
Months supply	6.46	−0.76	−0.79	−0.82	−0.85	−0.88	−0.88	−0.88	−0.88	−0.87
Foreclosure rate	16.32	−0.76	−0.79	−0.82	−0.85	−0.88	−0.84	−0.83	−0.82	−0.81
						No Search				
Output (Y)	1.00	0.86	0.89	0.93	0.97	1.00	0.96	0.93	0.89	0.86
House prices	1.58	0.82	0.85	0.89	0.92	0.96	0.95	0.94	0.92	0.91
Existing sales	8.15	0.26	0.28	0.30	0.32	0.33	0.29	0.25	0.21	0.17
Months supply	–	–	–	–	–	–	–	–	–	–
Foreclosure rate	–	–	–	–	–	–	–	–	–	–
						Recourse				
Output (Y)	1.00	0.86	0.90	0.93	0.97	1.00	0.97	0.93	0.90	0.86
House prices	1.68	0.81	0.85	0.88	0.92	0.95	0.94	0.92	0.91	0.89
Existing sales	5.99	0.25	0.26	0.28	0.29	0.30	0.31	0.32	0.33	0.33
Months supply	0.93	−0.75	−0.78	−0.81	−0.84	−0.87	−0.83	−0.80	−0.77	−0.75
Foreclosure rate	–	–	–	–	–	–	–	–	–	–

Note: Existing sales and months supply data span 1982–2010 and come from the National Association of Realtors. In the model, existing sales includes all REO sales and sales by owners. Foreclosure data are from the Mortgage Bankers' Association and cover 1979–2010. For house prices I use the Freddie Mac House Price Index. Data and model output are detrended with $\lambda = 10^8$ using the HP filter.

Table 12. Lagged correlations: household portfolios.

x	σ_x/σ_Y	Cross-Correlation of Output With								
		$x(-4)$	$x(-3)$	$x(-2)$	$x(-1)$	x	$x(+1)$	$x(+2)$	$x(+3)$	$x(+4)$
					Data					
Output (Y)	1.00	0.66	0.78	0.89	0.97	1.00	0.97	0.90	0.82	0.73
Net worth	1.84	0.55	0.66	0.74	0.77	0.77	0.75	0.71	0.68	0.63
Financial assets	1.76	0.49	0.58	0.65	0.67	0.65	0.62	0.59	0.55	0.51
Housing wealth	2.61	0.16	0.28	0.38	0.47	0.54	0.59	0.63	0.65	0.65
Mortgage debt	1.64	−0.15	−0.06	0.03	0.13	0.22	0.31	0.40	0.47	0.53
					Baseline					
Output (Y)	1.00	0.87	0.90	0.93	0.97	1.00	0.97	0.93	0.90	0.87
Net worth	1.71	0.76	0.79	0.82	0.86	0.89	0.90	0.90	0.90	0.90
Financial assets	1.61	0.77	0.81	0.84	0.88	0.91	0.93	0.93	0.93	0.93
Housing wealth	2.18	0.78	0.81	0.84	0.88	0.91	0.91	0.90	0.90	0.89
Mortgage debt	2.67	0.72	0.75	0.78	0.82	0.85	0.86	0.85	0.83	0.81
					No Search					
Output (Y)	1.00	0.86	0.89	0.93	0.97	1.00	0.96	0.93	0.89	0.86
Net worth	1.61	0.73	0.77	0.80	0.83	0.87	0.88	0.88	0.89	0.89
Financial assets	1.77	0.74	0.77	0.81	0.84	0.88	0.90	0.91	0.92	0.92
Housing wealth	1.78	0.77	0.80	0.84	0.87	0.91	0.91	0.90	0.89	0.88
Mortgage debt	2.44	0.78	0.81	0.85	0.89	0.92	0.94	0.95	0.94	0.93
					Recourse					
Output (Y)	1.00	0.86	0.90	0.93	0.97	1.00	0.97	0.93	0.90	0.86
Net worth	1.55	0.74	0.77	0.81	0.84	0.88	0.89	0.89	0.90	0.90
Financial assets	1.78	0.75	0.79	0.82	0.86	0.89	0.91	0.92	0.93	0.93
Housing wealth	1.83	0.77	0.80	0.84	0.88	0.91	0.91	0.90	0.89	0.88
Mortgage debt	2.98	0.74	0.78	0.81	0.85	0.88	0.89	0.89	0.88	0.87

Note: Net worth, financial assets, housing wealth, and mortgage debt data come from Table B.100 of the Federal Reserve Flow of Funds Accounts. Financial assets are defined as total financial assets plus consumer durables minus non-mortgage credit market liabilities. Housing wealth is defined as owner-occupied real estate at market values, and I use the home mortgages series for the definition of mortgage debt. I then define net worth as the sum of financial assets and housing wealth minus mortgage debt. Data and model output are detrended with $\lambda = 10^8$ using the HP filter.

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